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Eurasian watermilfoil (Myriophyllum spicatum L.) is a submersed aquatic angiosperm considered to be a very troublesome weed throughout the Eastern United States. Its rapid and effective dispersal, largely as plant fragments, and its ability to displace other macrophyte species through competition are major factors. Problems typically caused by Eurasian watermilfoil result from the large amounts of plant material that it produces near the water's surface. Additionally, detached plant material floats for a period of time and may interfere with water intake structures or simply wash up on shore and decay. Decomposition of transported fragments can lead to marked alterations of physical and chemical properties of the water that can have detrimental effects.

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# Ecological and Environmental Impacts of Eurasian Watermilfoil<sup>1</sup>

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## ABSTRACT

Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a submersed aquatic angiosperm considered to be a very troublesome weed throughout the Eastern United States. Its rapid and effective dispersal, largely as plant fragments, and its ability to displace other macrophyte species through competition are major factors. Problems typically caused by Eurasian watermilfoil result from the large amounts of plant material that it produces near the water's surface. Additionally, detached plant material floats for a period of time and may interfere with water intake structures or simply wash up on shore and decay. Decomposition of transported fragments can lead to marked alterations of physical and chemical properties of the water that can have detrimental effects.

## INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum* L.) was first described by Linnaeus in 1753 as occurring in Europe and was first reported from North America as early as 1814. The distinction between the Eurasian and American populations of watermilfoils has

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<sup>1</sup>The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.



been debated since Fernald named the American watermilfoil *Myriophyllum exalbescens* Fern.

As is common among many submersed angiosperms, the vascular system in milfoils is highly reduced in the number of xylem conducting elements and their degree of lignification. However, the importance of xylem as a conduction system should not be dismissed since this function may explain the presence of a casparian strip in the endodermis of the root. The phloem, on the other hand, is quite similar to that of terrestrial plants. The highly developed system of air spaces (lacunae) in milfoil is schizogenous in origin and represents an interactive morphological and physiological adaptation.

Milfoil is able to perpetuate itself by seed, by vegetative fragmentation, and by overwintering in an evergreen condition. The production of viable seeds requires emersion of the typically monocious flowering spikes with transfer of pollen by wind (anemophily) as the dominant pollination mechanism. Seed dispersal is aided by waterfowl and the floating inflorescence. With proper scarification up to 85% of the seeds germinate, but results indicate that under natural conditions seeds may actually have their germination delayed until at least their second spring. Seedling establishment appears to be a particularly fragile stage in the life-cycle. Fragmentation may be either accidental or the result of abscission. Abscissing fragments often develop roots at the nodes before separation from the parent plant. Fragments float for a period before they sink and thereby are dispersed. Although milfoil is typically herbaceous, it frequently overwinters in an evergreen form and may maintain considerable winter biomass. In other cases, overwintering occurs as new, unexpanded shoots attached to rootstocks. The overwintering shoots of milfoil do not usually consist of the compact, abortive leaf tissue generally associated with true turions.

Eurasian watermilfoil has become a pest only recently. It has spread widely in the Chesapeake Bay area and in the Northeastern states during the past 20 years. It was allegedly introduced into the Tennessee River watershed by implantation in the Piney River embayment of Watts Bar Lake near the Spring City Boat Dock in east Tennessee about 1953.

*M. spicatum* was first reported in North Carolina in 1959 when it was observed in one of the fresh-water impoundments on the Pea Island National Wildlife Refuge. The growth was eradicated in 1962 when ocean water overwashed the fresh water during a storm. Small patches of Eurasian watermilfoil were reported by Currituck Sound N.C. fishermen in 1964, but it was not positively identified until the following year when a localized primary area of infestation found in northern Currituck Sound was estimated to cover 40 ha. Rooted secondary growth of transplants that year were found over an additional 400 ha.

By the following summer (1966), a heavy infestation of watermilfoil covered some 3000 ha of Currituck Sound with another 27,000 ha supporting established growth. Areas of infestation in South Carolina were observed in Beck Bay, Albermarle Sound, Kitty Hawk Bay, Croatan Sound, and North River during the fall of 1966. A heavy but limited growth was observed in June 1970 for the first time on the south side of Albermarle Sound in East Lake near Haulover Point and in two isolated patches along Alligatorweed Creek,

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## BIONOMICS AND DISTRIBUTION<sup>2</sup>

Eurasian watermilfoil is a perennial having a wide range of environmental tolerances. The bottom surfaces on which it grows vary from muck to hard packed sand. It is found in fresh water as well as those waters ranging in salinity up to 16 parts per thousand (ppt). Exploratory aquarium experiments in Solomons, MD revealed that the plant grew most rapidly in fresh water, but it still showed vigorous growth at salinities up to 10 ppt. At 20 ppt, it remained alive during the summer, but grew very slowly. Most foliage died except near the growing stem tips. Eurasian watermilfoil can withstand considerable wave action and daily tidal fluctuation of several feet, but grows best in sheltered coves. Although it is most abundant in shallow (4 m) water, it has been found in clear water at depths of 6 m at high tide. Beds have also been found in 2 m of water in which turbidity at the time of the survey prevented sighting of objects below a depth of 1 m.

Reproduction and plant spread occur primarily by stem fragmentation. Small pieces of living stems with leaves are commonly observed drifting in the water, particularly in late fall. Additionally, plant fragments caught on boat motors, fishing gear, or embedded in cakes of drift ice are transported to new areas. If fragments lodge at the bottom, they produce roots and become anchored. Winter buds, separated from the stems, settle to the bottom, sprout with the advent of the new growing season, and comprise another means of reproduction. These buds may be scattered to other areas by tides and currents. Seeds are also formed and likewise distributed, particularly under conditions adverse to vegetative growth.

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<sup>2</sup> Abstracted from "Eurasian Watermilfoil", 217, Weed control Methods for Recreation Facilities Management, CRC Press, Boca Raton, FL, 1982

### *Distribution in the U.S.*

Eurasian watermilfoil is distributed over many areas of the U.S. in both south and north temperate climates, growing in both fresh and saline waters and rooted in hard-packed sandy soils. The plant tends to be limited to quiescent embayments and waters high in calcium. Growth is most aggressive where nutrient levels are high, but the plant will grow in waters not enriched. During the past 3 decades, it has been gradually distributed over most of the U.S.

### *Distribution in the British Isles*

The Agriculture Research Council (ARC), Weed Research Organization (WRO), Begbroke Hill, Kidlington, Oxford, England, was visited on August 10, 1967 by representatives of the Tennessee Valley Authority. The WRO was established by the ARC in 1960 as the official station in Britain for research and technical information about weed control on cropland. It has responsibilities dealing with plant control and management, management of waterways as a flood preventive measure, and of ditches adjacent to agricultural lands to promote good drainage and prevent soil waterlogging. Control methods being studied are mechanical cutting, herbicidal treatments, and biological control. Eurasian watermilfoil in general causes no major problem in England and requires no special program for its control. Inspection of a small tributary of the Thames River near the Oxford Field Station revealed a few small colonies of Eurasian watermilfoil. Inspections of several other potentially favorable areas for this species along the Thames River and in the Slough area gave negative results. Other field observations between London and Oxford concluded that Eurasian watermilfoil was not an important aquatic plant in any of the examined areas. In England there are three species of milfoil: *M. spicatum* (spike milfoil), *M. verticillatum* and *M. alterniflorum*. The milfoil was reported to be a native plant occurring in lakes, ponds, and ditches up to an elevation of approximately 400 m above sea level; nevertheless, it is mainly considered a lowland plant. It is locally common in some

areas, especially in calcerous waters, and has a wide geographical distribution in England. Spiked milfoil, sometimes a nuisance in English waterways, is not as troublesome as in certain areas of the U.S.

The Windermere Laboratory of the Fresh Water Biological Association, Westmore, England, was visited on August 15, 1967. Dr. H.C. Gilson, Director of the Station, discussed the Eurasian watermilfoil problem. He pointed out that Lake Windermere was a soft-water lake in a region of Silurian slates and Ordovician outcrops with a minor ring of Carboniferous limestone at its end. Soft-water lakes in general are unfavorable sites for *M. spicatum*, the species being found more abundantly in hard or calcerous lakes in southern England. In any event, *M. spicatum* reportedly occurs only sparsely in Lake Windermere, *M. verticillatum* is apparently more frequent here. Although *M. spicatum* was not seen growing in Windermere, herbarium species specimens collected from this lake were observed. Only three species of milfoil occurred in England, the third being *M. alterniflorum*, an inhabitant of peaty waters in non calcerous rock areas of western and northern England. Several shoreline areas of Lake Windermere between the Ferry House and Ambleside were inspected but Eurasian watermilfoil was not found. Specimens of *Potamogeton crispus*, *Elodea canadensis*, *Phragmites communis*, and other littoral plants were seen.

#### *Distribution in Eastern Europe*

On August 18 potential milfoil sites along the Seine River, Somme River, and other waterways between Paris and Antwerp were inspected. No problem areas of milfoil (*M. spicatum*) were found in waterways and ponds observed. Common plants noted at the Somme River included cane (*Phragmites communis*), cattail (*Typha latifolia*), white water lily (*Nymphaea alba*), and coontail (*Ceratophyllum demersum*). Watermilfoil (*M. spicatum*) was not found. On August 20, a trip was made by boat at Amsterdam to inspect

the Amstel River, several of the many canals, and the harbor area with seagoing vessels and dry docks. Milfoil (*M. spicatum*) was not found in any of the areas along the boat trip route.

#### *Distribution in Yugoslavia*

Eurasian watermilfoil is found in numerous areas of Yugoslavia and in many different habitats. Plant overpopulation disables fish production, limits the use of irrigation and drainage canals, disrupts recreation boating activities, and in some areas interferes with hydroelectric power production. It is localized in large bodies of water and forms colonies along river banks or in slow-moving water. Only in artificial habitats where there is shallow, quiescent water does it occupy the whole surface. If we separate those habitats in which watermilfoil is in regression, we find that these areas do not fully satisfy the ecological niche as we know it. Moreover, in new artificial lakes, Eurasian watermilfoil is not always found, although conditions are favorable. It is postulated that natural controls operate under these situations and prevent growth of watermil plants. These findings, in light of milfoil's well-established and wide distribution in Britain and Western Europe, support the view that Eurasian watermilfoil (*M. spicatum*) in its native environment does not present special problems as it does in the U.S. In this general area of origin, natural plant enemies are sufficient to provide natural control.

### **PROBLEMS ASSOCIATED WITH EURASIAN WATERMILFOIL**

Dense stands of Eurasian watermilfoil, like those of any other aquatic plant, completely usurp the occupied water area and render all recreation difficult, if not impossible. Boating and swimming are the principal recreational uses most vulnerable to drastic curtailment by dense stands of aquatic vegetation. Commercial fishing also becomes impossible in areas infested with Eurasian watermilfoil. A study in July 1963



(before Eurasian watermilfoil appeared) revealed that aquatic plant growth present was composed of 50% widgeon grass, 45% sage pondweed, and 5% redhead grass. In August 1966, the composition had shifted to 90% widgeon grass, 5% wild cherry, 1% redhead grass, and traces of naiad and sage. By 1968, Eurasian watermilfoil comprised an estimated 20 to 25% of the Kitty Hawk Bay plant composition, and in April 1973, it represented approximately 75% of aquatic vegetation. However, there is no evidence that displacement of high food value aquatics by watermilfoil has adversely affected waterfowl populations.

It is suggested that watermilfoil constitutes a human health problem by influencing the increase of disease-causing organisms. There have been charges that milfoil acts as a cultural medium for organisms causing botulism. In addition, it has been implied that milfoil is somehow connected with increases in fecal coliform counts (an indicator of potential disease problems due to water pollution). It has also been stated that dense milfoil mats enhance mosquito breeding by providing habitat for egg laying and hatching. The only botulism cases observed have been a few isolated cases of animal botulism affecting a few domestic ducks. The organisms causing these diseases are not harmful to man. There is no basis for charging that increases in fecal coliform are caused by Eurasian watermilfoil; however, the high density of milfoil indicated (as does fecal count) decreasing water quality. This decrease in quality may result from increased nutrients due to run-off from such sources as septic tanks. That milfoil mats do enhance mosquito breeding to some degree seems a valid charge. The magnitude and importance of this is unknown. Aesthetic revulsion causes part of the opposition to milfoil infestation. This latter charge is scientifically sound since decay of large milfoil amounts in fall can cause emission of hydrogen sulfide, which has an extremely obnoxious odor. Attempts to put visual or odorous displeasure in dollar terms is extremely difficult. However, it seems logically

sound to state that the negative value of milfoil in these terms may make a water area less desirable to some persons who frequent it for recreation, thus providing some degree of negative economic impact on the tourist industry. It is impossible to say whether the economic impact of this is compensated by increased numbers of freshwater fishermen who visit the area. (4) ,

## ENVIROMENTAL IMPACTS OF WATERMILFIL CONTROL

The selection of the particular herbicide type and amount to be used for milfoil control (butoxyethanal ester of 2,4-D) is a result of several different studies determining what herbicide has been used in similar situations with negligible environmental damage. Steenis and Stotts stated that granular butoxyethanal ester of 2,4-D, proves the most effective herbicide for for controlling Eurasian watermilfoil in the upper reaches of Chesapeake Bay. The Tennessee Valley Authority (TVA) has used 2,4-D extensively to treat watermilfoil at rates of 20 to 40 kg ae/ha granular 2,4-D BEE and has found it is very suitable for watermilfoil eradication and human safety.

The toxicity of 2,4-D to fish has been widely studied. Toxicity, while slight, appears to depend on the formulation used; physical conditions of the test: age, sex, and sensitivity of the species exposed; temperature and exposure time; and other factors. In the 1968 application of 2,4-D (20 kg ae/ha) on 2 A of watermilfoil in Currituck Sound, N.C. no acute effects on fish were observed. Other studies of toxicity to fish the acute and chronic concentrations from 500 to 800 ppm depending on conditions. It is anticipated that concentration in the water from the application 20 ae/ha will not exceed 100 ppb almost immediately after application because of rapid herbicide absorption on the vegetation surfaces and dilution caused by water circulation in the treatment vicinity. For this reason,

no toxic effect on fish population is observed. Benthic organisms (glass shrimp, damselfly nymphs, scuds, and blue crabs) showed no adverse effects in the 1968 application of 2,4-D in Currituck Sound. In the monitoring of the 1968 watermilfoil treatment, plankton samples indicated no significant variation in numbers of species.

Watermilfoil is extremely susceptible to 2,4-D. The herbicide is absorbed on the plant surface and subsequently absorbed into plant tissues. Observations indicate that the herbicide is specifically effective on watermilfoil and is not harmful to most other aquatic species in the area such as southern naiad (*Najas guadalupensis*), wild cherry (*Vallisneria americana*), redhead grass (*Potamogeton perfoliatus*), sage pondweed (*P. perfoliatus*), and widgeon grass (*Ruppia maritima*). Growth of these species increases with the decrease in population of dominant watermilfoil. This is beneficial to waterfowl since these are preferred food species. There is some potential damage to shoreline terrestrial vegetation by accidental application. Care must be taken in application to minimize chance of any deposition on terrestrial areas. Meteorological conditions, particularly wind velocity and direction, must be checked to insure no drift of the aerially applied granules, but granule application itself is a safety factor.

Postapplication sampling after the 1968 treatment of 2,4-D on 80 ha in Currituck Sound indicated no change in overall water quality of the treated area and no water samples containing residues of more than 10 ppm of the herbicide. The persistence of 2,4-D is determined by a variety of factors: rate of treatment, frequency of application, extent of dilution, biodegradation by microorganisms, metabolism by plants, temperature, and time. In the TVA studies, concentration of the chemical disappeared from water samples within 3 days to 2 weeks. Residue levels in water immediately fell to 100 ppb or less after application and dissipated within 3 weeks after treatment. Residues in fish and benthos also decreased to levels below the detectable limit of 0.10 ppm in the same pattern.

In more than 20 years of extensive use, no recorded incidents of biological herbicide magnification in food chains exist. In summary, there appears to be no significant opportunity for potential long-term effects on the biological accumulation of 2,4-D.

The probability of human exposure to even transitory toxic concentration of 2,4-D during milfoil control activity is extremely remote. Problems associated with acute toxicity of 2,4-D to humans are likely only with purposeful or accidental ingestion of large amounts of undiluted 2,4-D. It is reported that acute fatal poisoning occurs from ingestion of 62 g, and single oral doses of 2 to 4 g are necessary to produce symptoms in humans. The toxicity of 2,4-D to domestic animals varies. The dose required to kill 50% of a population in a given time, LD for rats, guinea pigs, and rabbits, ranges from 300 to 1000 mg/kg of body weight. (1-9),

## SUMMARY AND CONCLUSIONS

The primary purpose of milfoil control is to alleviate social and economic problems associated with watermilfoil infestation. The areas selected for treatment are those where the greatest need exists to alleviate social and economic problems of the citizens involved. The primary social impact of milfoil control will be increase in recreational water activity allowed by transformation of the area from weed infested to open water (allowing passage of recreational boating through the infestation) and increased visual aesthetic quality.

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